

The biology of the threatened Green-thighed frog *Litoria brevipalmata* (Anura: Hylidae) in the central and mid-north coastal areas of New South Wales

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ABSTRACT

We undertook field work (aural and visual surveys) and a literature review to obtain information on the biology of the Green-thighed Frog including the location and timing of calling events, the types of ponds used for calling and aspects of tadpole biology. Calling occurs from September to April and is strongly dependent on rainfall events. Chorus size ranged from 1 to over 100 males. Fifty eight percent of records (n = 45) were of 2 to 10 males. Calling at a site did not exceed more than two consecutive nights at a time (11 occasions) and usually lasted one night (20 occasions). Calling sometimes occurred once per season per site (36%), often did not occur at all in a season (26 occasions) and was heard three times at one site just once. Calling was sporadic and unpredictable, usually occurring at only one or two of the Bulahdelah sites on any given night. Calling and breeding was almost exclusively confined to natural or artificial ephemeral water bodies. Clutches are laid as floating rafts and embryos hatch within 24 hours. Tadpole metamorphosis occurred in 40 days or less, or took over 100 days. Most calling sites occur within forested habitats. The Green-thighed Frog may cope with some land disturbance, for example logging or partial clearing, but it appears likely this species has suffered historically from clearing and will continue to do so.

Key words: Calling season, conservation, breeding sites, *Litoria brevipalmata*

Introduction

The Green-thighed Frog *Litoria brevipalmata* is a recently described Hylid frog (Tyler *et al.* 1972) found in forests and swamps of the coast and adjacent ranges from central New South Wales (NSW) to south-east Queensland (Figure 1, Cogger 2000; Barker *et al.* 1995, Hines *et al.* 1999). Details of its biology are limited and uncertain, which limits successful management of the species. Robinson (1993), Griffiths (1997) and Cogger (2000) list the breeding season as summer whereas Barker *et al.* (1995) record it as October and January. Calling has been documented to last for only a few days at a time (Natrass and Ingram 1993; Barker *et al.* 1995) and has been noted to occur in association with “heavy rains” (Barker *et al.* 1995; Ehmann 1997). Males are noted to call around flooded semi-permanent or ephemeral pools, usually in grassy areas (Robinson 1993; Barker *et al.* 1995; Cogger 2000). Anstis (2002) records the size of three clutches to vary from 366 to 582 eggs, with hatching occurring after three to four days and metamorphosis at six to ten weeks after laying.

This species may have varying habitat requirements across its range. Cogger (2000), Robinson (1993) and Barker *et al.* (1995) all record this species to be associated with moist forests (swamp forests, wet sclerophyll forest and rainforest). However, records from the northern parts of its range appear to predominantly come from dry sclerophyll forest (McDonald 1974; Czechura 1978; Natrass and Ingram 1993; Ardis, 1996) and this may also be the case

for far northern NSW (Murphy and Turbill 1999; Ken McCray and Mark Fitzgerald, pers. comms.).

The Green-thighed Frog is listed as vulnerable in New South Wales (*Threatened Species Conservation Act 1995*) and rare in Queensland (*Nature Conservation Act 1992*). Nationally, this frog has been listed under the Action Plan for Australian Frogs as insufficiently known (Tyler 1997). Tyler (1992) considered this species to be vulnerable. Ehmann (1997) listed this frog to be vulnerable under IUCN rankings, but also considered that it was “probably secure”, although further study was required to confirm this status. This was based on the assessment that “disturbance is a feature of all known sites” and that the rarity of records was probably much more a result of being “mostly undetectable”. Threats for this species were listed as loss of water quality, habitat fragmentation and/or loss, climate change and intensive forestry, particularly any future intensification of forestry activity. Hines *et al.* (1999) note that habitat loss (in particular), fire, timber harvesting, grazing, weed invasion and changes to hydrology and water quality all may be disturbances that affect this species, but their level of impact was unknown. More recently, this species has been listed as Endangered under the IUCN (2001) criteria. The reasons for this are “*L. brevipalmata* has a broad distribution, however, this is severely fragmented and the species occurs in isolated subpopulations. Loss

and degradation of habitat is ongoing" (2003 IUCN Red List of Threatened Species - <http://www.redlist.org>).

We provide an updated list of locality records for Green-thighed Frogs within NSW and draw together existing and new information on the biology of this species, particularly in respect to mid-coastal areas of NSW. We discuss the methods required to successfully survey for this species, list its breeding habitat requirements for at least the southern part of its range, and consider the impacts of human disturbances. In doing so, we hope to assist in successful long-term management of the Green-thighed Frog.

Methods

The majority of the work presented in this study is based on a five-year monitoring program, commencing in the spring of 1996, of eight Green-thighed Frog breeding sites in the Bulahdelah area of New South Wales (Figure 1; Lemckert et al. 1997). The breeding sites were visited between November and April, *a priori* assumptions, based on observations by two of us (FL and CS), being that calling activity did not commence until ephemeral pools at some sites filled to at least 5 cm (estimated depth). This happened only after heavy rain periods, usually >50 mm in 24 hours. Pond depths were not measured, however a

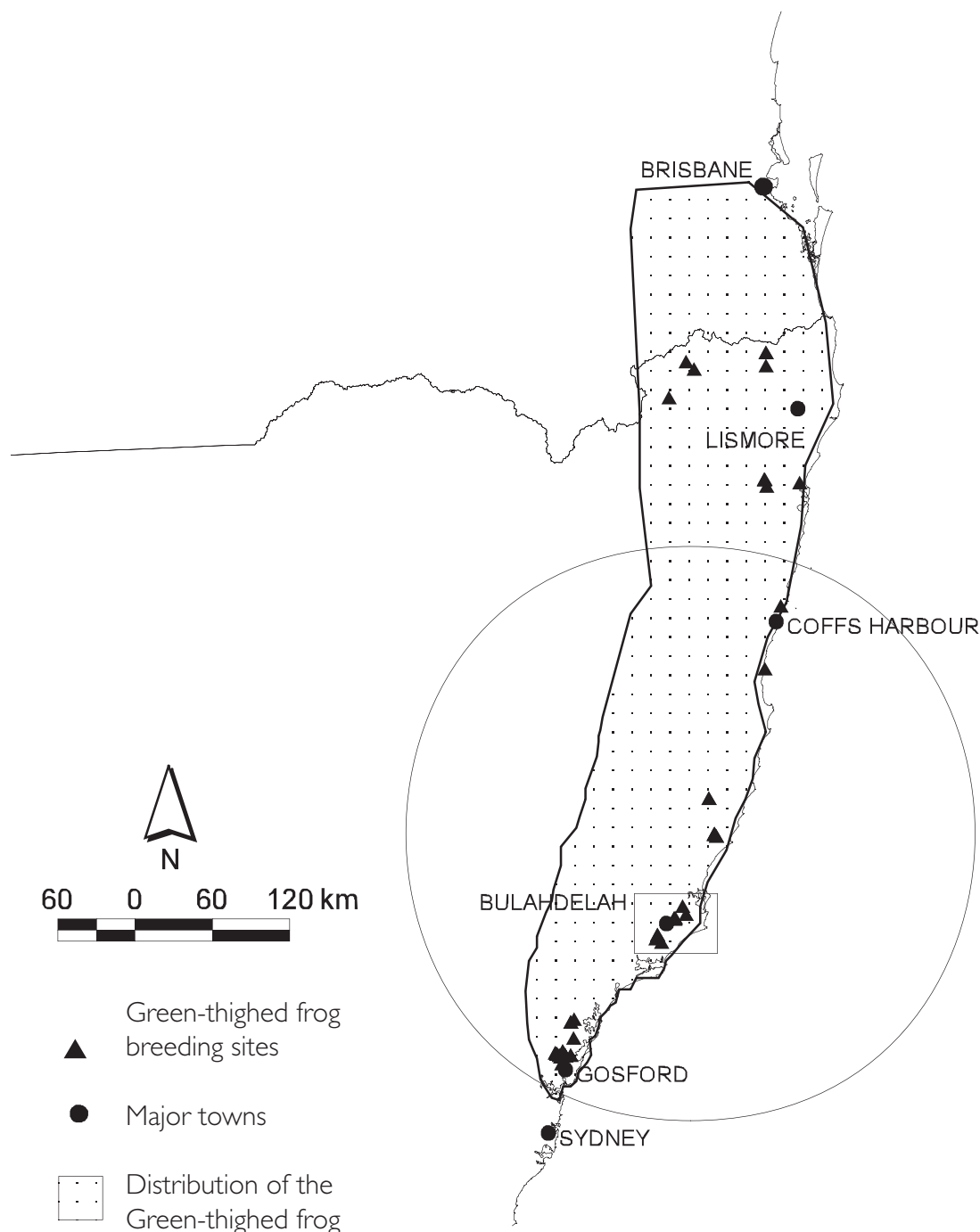


Figure 1. Distribution of Green-thighed Frog records throughout New South Wales. The inset shows the scatter of records in the Bulahdelah region

description of water level was reported on 40 occasions. Sites were surveyed for up to three consecutive nights. Sites were inspected at least once after dusk to determine the extent of flooding and a minimum of five minutes was spent identifying the calls of frogs. This was followed by a visual survey of the flooded area and the surrounding vegetation. Surveys took a minimum of 15 minutes, usually

around 30 minutes and sometimes more than 60 minutes, depending on the size of the site, density of frogs and the presence of vegetation. If a suspected Green-thighed Frog was heard, the frog was located visually to confirm its identity (their calls are easily confused with some species in the rocket frog *Litoria nasuta*, species group). Other species calling at the sites were also recorded (Table 2).

Table 1. A list of records of the green-thighed frog from New South Wales along with associated habitat information, where available (For habitats RF = Rainforest, WS = Wet Sclerophyll, DS = Dry Sclerophyll, SwF = Swamp Forest, PC = Partly Cleared)

Site	AMG	Record Year/s	Pond Type	Habitat	Reference
1. Byabarra	NA	1970	Ephem	NA	Tyler et al, 1972
2. Ourimbah	346495 6306834	1971	Ephem	NA	Tyler et al, 1972, Cogger, pers. comm.
3. Ourimbah	NA	1981, 91	Ephem	RF	Mahoney, pers. obs.
4. Ourimbah	342650 6310900	1995	Perm	RF	Gow, pers. comm.
5. Ourimbah SF	NA	1992	Ephem	WS	Schmida & Swanson pers. comm.
6. Ourimbah SF	347300 6313700	1992	Ephem	WS	Schmida & Swanson pers. comm.
7. Ourimbah SF	346850 6315200	1997, 99	Ephem	WS/DS	Recsei, pers. comm.; Lemckert, pers. obs.
8. Ourimbah SF	346200 6312800	1990, 99	Perm	DS/WS	Lemckert, pers. obs.
9. Ourimbah	347300 6311400	1990, 91, 96, 97	Ephem	WS	Lemckert, pers. obs.
10. Wattagan SF	NA	1994	Ephem	WS	Mahony, pers. obs.
11. Martinsville	332500 6332400	1991	Ephem	DS	Mahony, pers. obs.
12. Berkelyvale	351500 6311500	1995	Ephem	WS/DS	R. Wellington, pers. comm.
13. Bulahdelah SF	431770 6417600	1995, 96, 98	Ephem	WS	Lemckert et al, 1997; Lemckert, pers. obs.
14. Bulahdelah	440500 6420950	1996 to 99	Ephem	DS/WS	Lemckert et al, 1997
15. Bulahdelah SF	431800 6417500	1998, 99	Ephem	WS	Lemckert, pers. obs.
16. Bulahdelah	436150 6428950	1996	Ephem	WS/PC	Lemckert et al, 1997
17. Nerong SF	421650 6399400	1996, 98	Ephem	WS/DS	Lemckert et al, 1997
18. Nerong SF		1998	Ephem	WS	Lemckert, pers. obs.
19. Nerong SF	418700 6404910	1997, 98	Ephem	WS	Lemckert et al, 1997; Lemckert, pers. obs.
20. Nerong SF	417510 6401790	1997, 98	Ephem	WS	Lemckert et al, 1997, Lemckert, pers. obs.
21. Landsdowne SF	462650 6483100	1995	Ephem	WS	White, pers. comm.
22. Landsdowne SF	462850 6483360	1995, 96	Ephem	WS	White, pers. comm.
23. Coopernook SF	464150 6481700	1995	Ephem	WS	White, pers. comm.
24. Wauchope	474010 6515800	1998	Ephem	WS	M. Potter, pers. comm.
25. Wauchope	458450 6510900	1998	Ephem	WS	J. Williams, pers. comm.
26. Wauchope	458450 6510900	1998	Ephem	PC/DS	M. Potter, pers. comm.
27. Nambucca	501990 6611580	1998	Ephem	SwF	F. Lemckert, pers. obs.
28. Wild Cattle Creek SF	480100 6661800	1990, 91	Ephem	WS	A. Manning, pers. comm.
29. Bundjalung INP	529120 6755000	1998	Ephem	CF	Murphy & Turbill, 1999
30. Whiporie	501300 6783000	1993, 94	Ephem	DS	J. Cavanaugh, 1996
31. Richmond Range SF	NA	1995	Ephem	RF	M. Mahony, pers. obs.
32. Tooloom Range	514472 6884370	NA	Ephem	NA	Smith, 1995
33. Tooloom Range	514410 6884960	NA	Ephem	NA	Smith, 1995
34. Nightcap Range	515700 6825100	1987	Ephem	NA	Milledge, 1987
35. Nightcap Range	534800 6850500	1987	Ephem	NA	Milledge, 1987
36. Sheepstation Creek	502700 6856900	1992, 95	Ephem	WS/RF	K. Cherry, pers. comm.; Mahony, pers. obs.

Additional data on calling activity were obtained from various other sources (see Table 1). All NSW records are included in the distribution map, but only records located between the Gosford and Coffs Harbour (Figure 1) were used in the analysis and assessment of its biology. North of Coffs Harbour, there are indications that the broad habitat associations of the Green-thighed Frog may vary and we have insufficient records for a suitable comparison. For “southern” records, we collected the location (Australian Map Grid Reference – AMG), the number of calling males, the length of calling event and the temperature at time of calling, where possible.

We assessed the influence of rainfall on calling activity using information and records from the Bulahdelah area where our rainfall (from the Bulahdelah Post Office) and calling records were relatively accurate. We used logistic regression to assess the effect on Green-thighed Frog calling by rainfall 24 and 72 hours prior to the surveys. SAS Version 8 was used for analysis.

Where it was available we collated the following information for each breeding pool: ephemeral or permanent, artificial or natural, closer or further than 100 m from a patch of vegetation larger than 100 ha, and forest type (based on Anon 1989). This allowed us to determine any typical features of the habitat at calling sites.

Results

Breeding Sites

The types of breeding sites used by this species are recorded in Table 1. The breeding sites are predominantly

Table 2. Species of frogs also recorded at *Litoria brevipalmata* calling sites

species	Number of sites where detected
<i>Adelotus brevis</i>	2
<i>Crinia signifera</i>	8
<i>Limnodynastes peronii</i>	8
<i>Limnodynastes tasmaniensis</i>	3
<i>Litoria chloris</i>	2
<i>Litoria dentata</i>	5
<i>Litoria fallax</i>	7
<i>Litoria freycineti</i>	1
<i>Litoria gracilentata</i>	5
<i>Litoria latopalmata</i>	4
<i>Litoria lesueuri</i>	1
<i>Litoria nasuta</i>	2
<i>Litoria peronii</i>	3
<i>Litoria phyllochroa</i>	1
<i>Litoria revelata</i>	7
<i>Litoria tyleri</i>	5
<i>Litoria verreauxii</i>	3
<i>Mixophyes fasciolatus</i>	5
<i>Pseudophryne coriacea</i>	8
<i>Uperoleia fusca</i>	6

ephemeral pools (35 of 37 sites = 95%) partly or wholly within rainforest or wet sclerophyll forest (26 out of 31 sites = 84%; Table 1). There are however, two records of calling from around permanent, artificial ponds and three records wholly within dry sclerophyll forest, one from swamp forest behind a beach (around 100 m from the sea) and another from coastal forest (Table 1). Natural depressions adjacent to streams (eg old billabongs) were the most commonly used calling sites recorded for the Green-thighed Frog. Males do however, also call and breed at artificial water bodies with close to half (12 of 27) of the sites being human excavated hollows or flooded road verges. Twenty-two pools were leaf and shrub filled depressions, whereas five had significant amounts of grass in and around them.

A broad range of species, 19 in total, were recorded breeding in the same locations as *Litoria brevipalmata* and these are listed in Table 2. Most are widespread species and the commonly associated ones are well known for breeding in temporary water bodies.

Calling season and calling activity

In the southern part of their range, Green-thighed Frogs have been recorded to call from September to May (70 records in total). The month with the greatest number of calling events is January (n = 27) and 90% of all records occur between November and February (Figure 2) and the latter can generally be considered their core calling season.

In the Bulahdelah area we have 125 site samples, with frog species recorded, from the nine known calling sites of the Green-thighed Frog. On 43 occasions we recorded calling at a site and so on 86 occasions (66%) frogs were not calling. On 49 occasions there were no Green-thighed Frogs calling anywhere in the area. This work provided the bulk of the following information. In the early stages of the study one of us (CS) made >20 visits to selected sites during periods of rainfall. When there was no sign of Green-thighed Frogs or flooding, these visits were not recorded for analysis and are not included in the 125 site samples above.

The duration of the recorded calling events has been brief, with a median of one night and a mean of 1.4 nights (n = 31; SD 0.5). In our samples, we rarely surveyed beyond two consecutive nights, so we cannot discount occasional longer calling periods, but we stopped recording because the frogs had ceased to call. We know of four occasions where two calling events (more than 20 days apart) occurred at a site within a breeding season and one instance of three calling events in a season. Calling activity for *Litoria brevipalmata* has been recorded between dusk and mid-morning at these sites.

The largest number of males recorded calling at a breeding site was at least 100 (and possibly more than 200) from a flooded swamp forest near Bulahdelah in November 1998. The minimum of one calling male has been recorded on six occasions. Most commonly, the number of calling males ranges between two and ten frogs (26 of 45 available records).

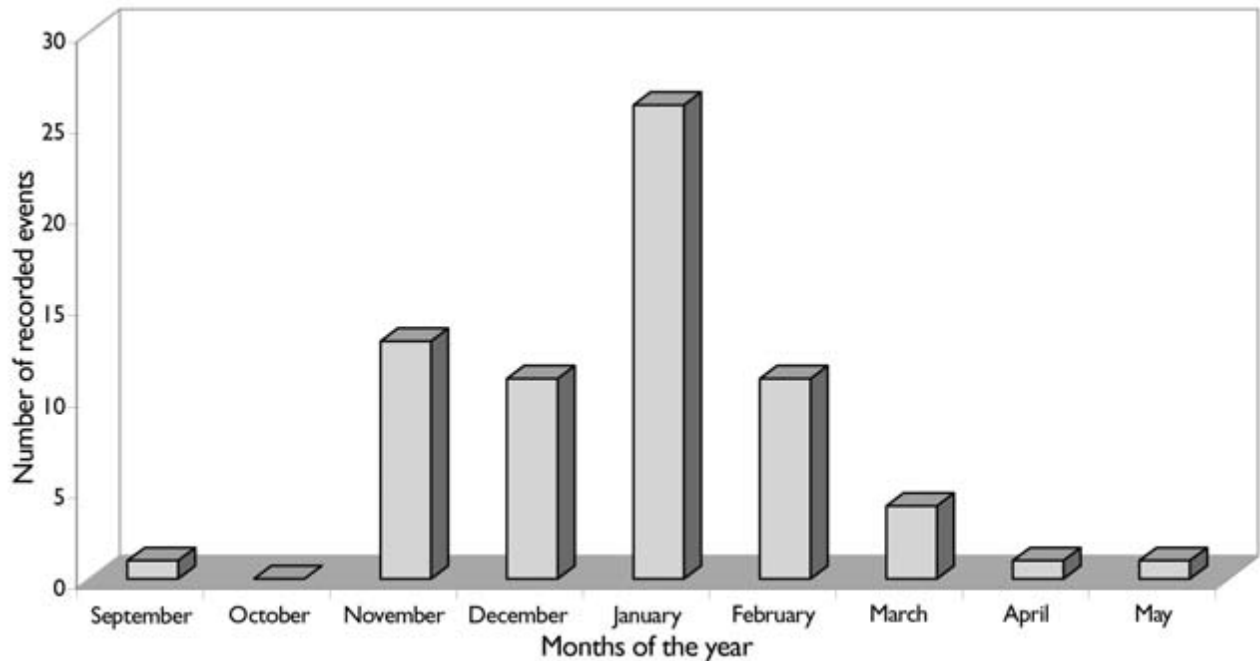


Figure 2. A histogram of Green-thighed Frog calling events recorded for each month of the year

Pond depth was not measured, however on more than 80% of surveys when the males were calling, the sites were flooded to their maximum extent and calling never occurred where flooding was not at least 75% of the available area (F. Lemckert and C. Slatyer pers. obs.).

The Bulahdelah monitoring found calling to be sporadic and unpredictable in nature at the known sites. We visited all the Bulahdelah sites in one night on 17 occasions, but never recorded calling at all sites on any one night. Once we recorded calling at all but one site, twice (12%) half the sites or more had males calling at them, nine times males were calling at two sites and seven times we recorded only one site with calling males. Whilst we could not be absolutely certain that some brief calling did not occur on some occasions, we are certain that this could only be a rare event at best (based on our experience and all the literature information).

Rainfall and Temperature

Rainfall for the 24 and 72 hours prior to 11 calling records from the Bulahdelah area are recorded in Table 3. They ranged from 24 mm to 125 mm (24 hours) and 24 mm to 217 mm (72 hours). 50% of breeding records occurred after 67 mm and 89.9 mm had fallen within the last 24 and 72 hours, respectively. Logistic regression analysis was used to determine if calling of Green-thighed Frogs was a directly associated with rainfall. Comparisons of presence or absence of calling with recorded rainfall for 31 survey events showed a significant increase in the probability of calling Green-thighed Frogs being found as rainfall increased when rainfall for both the previous 24 (Wald $\chi^2 = 6.81$; $P < 0.01$) and 72 hours (Wald $\chi^2 = 7.77$; $P < 0.01$). We note also that we did not record and are not aware of any occasion where Green-thighed Frogs have been heard calling when rainfall had not occurred during the previous day or even the previous few hours.

The temperature at the time of calling ranged from 13°C to 22°C.

Eggs and Tadpoles

Seven egg masses were identified with spawning Green-thighed Frogs. All were laid as a single-layer surface film that floated for up to 24 hours. One pair of frogs collected in amplexus in the Bulahdelah area and placed in a bucket produced a clutch of between 380 and 410 eggs that all hatched within 48 hours of deposition. This clutch was kept in a tank in a lab and the first metamorphlings appeared after 52 days and 50% had metamorphosed by 70 days. However, 5% of the tadpoles had still not metamorphosed after 100 days. In the field, metamorphlings have been located around a fully exposed shallow, grassy pool 40 days after recorded calling activity and around a dried pool 39 days after calling. The pool at the latter site had been dry an estimated five days and the time to reach metamorphosis was probably 34 days or less. This is considerably faster than the “lab” raised frogs and slightly shorter than the six weeks reported by Anstis (2002).

Discussion

Calling Site Requirements

Our data confirm the views of guides such as Cogger (2000) and Barker *et al.* (1995) that, at least in the southern part of its range, Green-thighed Frogs usually call (and presumably breed) in temporary water bodies that are located within or near areas of wetter forest types. These sites are usually depressions with a leafy/shrubby substrate rather than grass filled. This information can be used as a broad guide to where calling sites for Green-thighed Frogs are most likely to be found. The two records from permanent water bodies and two associated with dry forests can be considered to be unusual. A more detailed analyses of habitat variables at the known calling sites is proposed for the future and this information may provide more detail on breeding pond requirements for our selected area.

Table 3. Information for 31 calling events of the Green-thighed Frog recorded at Bulahdelah, NSW. (Note: This table only includes records where the majority of the categories could be completed).

No. calling males	Month	Days of Calling	Natural or Man made	Maximum Pool Size m ³	Rainfall (24/72 hrs)	Temp C	Forest < 100m away
9	November	1	Natural	600	119/166	NA	yes
100	November	2	Natural	NA	119/166	14	yes
4	November	2	Natural	42	119/166	14	yes
2	November	2	Man made	50	119/166	14	yes
1	November	1	Natural	NA	119/166	NA	yes
5	November	2	Natural	225	119/166	14	yes
4	November	2	Man made	60	119/166	14	no
3	November	1	Man made	60	30.7/80.7	NA	no
2	December	1	Man made	50	NA	14.3	yes
7	December	1	Natural	600	NA	15	yes
6	December	1	Man made	60	NA	NA	no
12	December	1	Natural	NA	NA	14.8	yes
10	January	1	Natural	600	79/94	20.5	yes
5	January	1	Natural	600	44/72	20.5	yes
1	January	1	Man made	50	44/72	NA	yes
20	January	2	Man made	60	44/72	22	no
5	January	1	Natural	NA	50.5/50.5	19.3	yes
32	January	2	Man made	60	50.5/50.5	19.3	no
6	January	1	Natural	NA	NA	NA	yes
2	January	2	Man made	50	74.5/74.5	19	yes
40	Jan/Feb	2	Natural	225	97/109.5	19	yes
4	Jan/Feb	2	Man made	60	97/109.5	21.5	no
2	February	2	Natural	NA	24.4/24.4	22	yes
1	February	1	Man made	60	24.4/24.4	22	no
2	February	1	Man made	60	30/30	18	no
1	February	1	Natural	42	63.5/63.5	NA	yes
40	February	1	Natural	225	63.5/63.5	20.3	yes
4	March	1	Natural	225	75.5/80	22	yes
1	March	1	Natural	NA	75.5/82	22	yes
2	March	1	Natural	225	75.5/82	22	yes
3	March	1	Man made	60	75.5/82	22	no

Calling Habits

The Green-thighed Frog in the southern half of its range has a broad potential calling season (all months in spring, summer and autumn), although they are more likely to be heard from November to February, the warmest months of the year. This contrasts with the statements of most field guides that note calling occurs either in the summer months (Griffiths 1997; Anstis 2002) or in spring and summer (Barker *et al.* 1995; Robinson 1995; Cogger 2000). These guides miss at least March to May, which is an important consideration when planning surveys for this frog. There may be a preference for calling during warmer conditions, but this is not clearly the case and frogs have called when conditions were relatively cool. It may be that these are the months most likely to have the types of rainfall patterns that can fill ponds.

The Green-thighed Frog is far more likely to call after rainfall events that are significantly above the mean daily or three daily levels for the given time of the year. This appears to be directly related to the flooding of the breeding ponds as no calling has been seen to take place if the ponds have not filled, regardless of the amount of rain that has fallen. The suggestion that they call after heavy rain has been made in most of the field guides, but the importance of filling the pools to a significant extent has not been made. Heavy rain is not sufficient in itself to induce calling if the ponds have not yet filled.

The data indicate that the Green-thighed Frog has the lowest number of calling days of any temperate Australian anuran species. In the Bulahdelah region, the maximum total recorded number of nights of calling activity at any site in a season was just five, and we recorded only one day or less per season 80% of the time. It is possible that some calling was missed, but all of the literature records

and our records demonstrate that calling is associated with rainfall events that produce flooding of potential breeding sites. We visited the sites any time this seemed possible, but never heard calling when flooding had not occurred, which strongly suggests that other calling is highly unlikely to have occurred and these figures should be very close to correct. We also cannot be certain that this behaviour is consistent through all regions, but the literature suggests that calling is rare and sporadic throughout the range of the Green-thighed Frog. Other temperate Australian species that breed in semi-permanent to permanent water bodies have calling seasons lasting several months. During this period males call on most nights when conditions are suitable (Dankers 1977; Humphries 1979). Species that prefer temporary water bodies to breed in (eg, *Litoria chloris*, *Lechriodus fletcheri*) are usually heard far less consistently, but can still be heard calling on many different nights in a season after rainfall (F. Lemckert and M. Mahony, pers. obs.). The reasons for the brevity of the calling activity of Green-thighed Frogs compared to other species are uncertain. Such a strategy appears risky as poor rainfall can prevent any calling within a season and ponds have been seen to dry out within two weeks of calling activity (F. Lemckert, pers. obs.). This is likely to leave Green-thighed Frogs susceptible to significant population swings, increasing the threat of localised extinctions during successive poor years.

There is a question as to whether calling season equates to breeding season for this species? We cannot answer this question as we are unable to determine that breeding had or had not occurred at most events. We were only certain when we saw eggs produced as even an amplexing female is not certain to produce a clutch of eggs. We do however, believe that calling season and breeding season are the same because of the very limited breeding opportunities available for this frog. It would seem very unlikely that females would ignore quite possibly the one night only in a season when they could reproduce in hope that another night will arise later. Hence we can expect that they will take advantage of any calling event and so calling season = breeding season.

Threats

All but one Green-thighed frog calling site in this study was located within 100 m of a tract of natural vegetation greater than 20 ha and none was found in largely cleared (>50%) grazing lands or within entirely urban areas. This is likely to be due to their preference for low shrubs and leaf litter as shelter (Lemckert and Slatyer 2002). Habitat

loss on a broad scale is clearly an issue and this frog would have declined in numbers through more extensively cleared parts of its range and particularly the coastal plain (Mahony 1996; Hines *et al.* 1999). On the other hand, our information supports the idea of Ehmann 1997, that this frog has some tolerance for disturbance as both he and we found all sites to have had some form or another of disturbance. Partial clearance of vegetation within an area does not appear to prevent Green-thighed Frogs calling at a site as many populations on the central and mid-north coast of New South Wales fall within mosaics of cleared and naturally vegetated areas (eg, the Ourimbah area). This point is of value in conserving the Green-thighed Frog, as redeveloping properly interconnected larger patches of vegetation within partly cleared lands may allow this species to persist or re-establish populations.

Both Hines *et al.* (1999) and Ehmann (1997) consider logging to be a potential threat to the Green-thighed Frog and the impacts of forestry activities remain uncertain. Sixteen (44%) of the listed calling sites are found within State Forests, all of which have been subjected to multiple logging associated disturbances for at least 50 years. Given the presence of so many populations in these forests, often in areas with a very recent history of disturbance, it suggests that the effects of logging on the Green-thighed Frog are not catastrophic and have not lead to large-scale extinctions. Logging causes a mosaic of disturbed and undisturbed patches of forest, much like where populations remain in partly cleared lands, but with a relatively less and temporary disturbance as compared to partial clearing for agriculture. As a minimum 50% of all logging areas remaining unlogged under current regulations (NPWS 1997), the impacts would appear less than that of permanent localised clearing.

Fire is a possible threat to the green-thighed frog due to its use of low vegetation and leaf litter for shelter (Lemckert and Slatyer 2002). The seriousness of this threat is unknown, but one calling site at Bulahdelah had been subjected to a severe wildfire in the early 1990s that removed all vegetation around the pond, including the tree canopy. This site has been used regularly since at least 1995, indicating that the Green-thighed Frog can sometimes survive in or rapidly recolonise severely burnt areas. Multiple disturbance events in rapid succession that remove ground cover and shrubs may be a more serious problem that requires investigation. The threat to southern populations may also not be as great due to their general association with moist forests.

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APPENDIX I



Green-thighed frogs in amplexus at the edge of a temporary pool.
Photo: F. Lemckert



Typical green-thighed frog breeding habitat: an old ox-bow lake near Bulahdelah on the lower north coast of NSW.
Photo: F. Lemckert